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High Vibration Due to Steam Turbine Deposits

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Presenter Bios

Dr. John Yu joined Bently Rotor Dynamics Research Corporation in 1998, followed by General Electric - Bently Nevada in 2002, He has performed not only rotor dynamic research but also machinery vibration diagnostics for customers worldwide, and is now Senior Technical Manager in Machinery Diagnostic Services. He has over 50 technical papers in journals and conferences. He holds a PhD in Mechanical Engineering from University of Alberta, and is an ASME Fellow.

Carl Feng Wang joined Shanghai SECCO Petrochemical Co. in 2003, serving as Maintenance Manager responsible for all the equipment maintenance for the company. Since 2012, he has served as Machinery Manager, responsible for equipment reliability and condition monitoring. He has been collaborating closely with Bently Nevada to identify machinery malfunctions and avoid potential failures successfully.

Nicolas Peton joined GE in 2006 in the Machinery Diagnostic Services group. Previously he worked for two different manufacturers (Alstom Steam turbine and Cryostar expander/compressor) where he was in charge of on site of the startup activities worldwide. He also worked as an operation and maintenance engineer in the chemical industry (PPG industry, USA) and as Free Lance for startup activities worldwide. He has been also a mechanical/acoustical research engineer in research institutes (Technion, Haifa and TU Berlin). He is currently Global Director for the Machinery Diagnostic Services. He has a Diplome d'ingénieur from the Université de Technologie de Compiègne, France.

Abstract

This presentation provides a case study how to correctly deal with increased vibration on a steam turbine that drives a compressor. After the machine had not operated for a week, vibration level increased 5 times during its re-startup. An in-depth review of vibration data did not seem to indicate malfunctions other than a possible unbalance issue. Balancing would be a quick fix to let this machine back in service. However, as the root-cause remained unknown, it was decided to disassemble the turbine for inspection instead. Large amounts of deposit were found on turbine blades. Had balancing performed in this case without examining the root-cause, the machine could have tripped later suddenly to affect the entire operation in this petrochemical facility.

Outline

1. Introduction
2. Problem Statement
3. Data Review
4. Conclusions and Recommendations
5. Inspection and Findings
6. Resolution and Final Vibration Results
7. Lessons Learned

1. Introduction

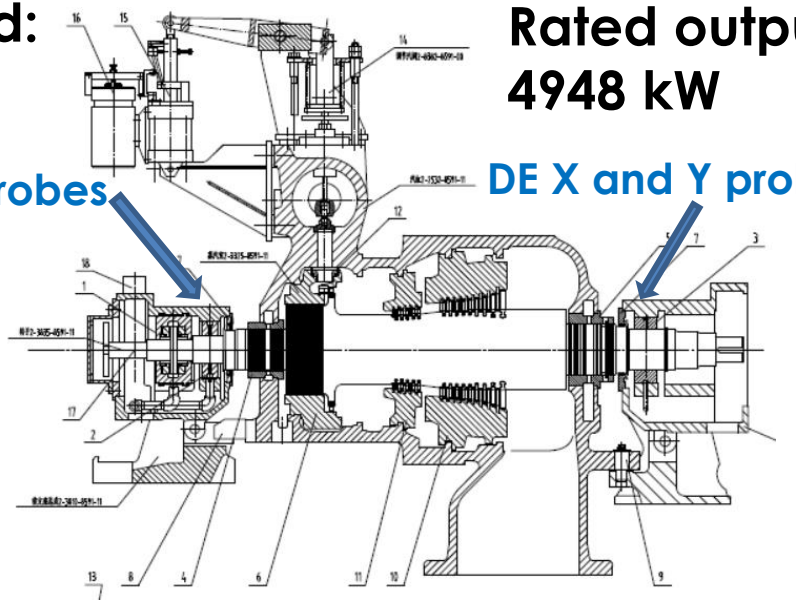
- ***Back pressure steam turbine*** driving an air compressor via flexible membrane disc coupling.
- Vibration monitored by proximity probes at each bearing.

Rated speed:
7656 rpm

Rated output:
4948 kW

NDE X and Y probes

DE X and Y probes

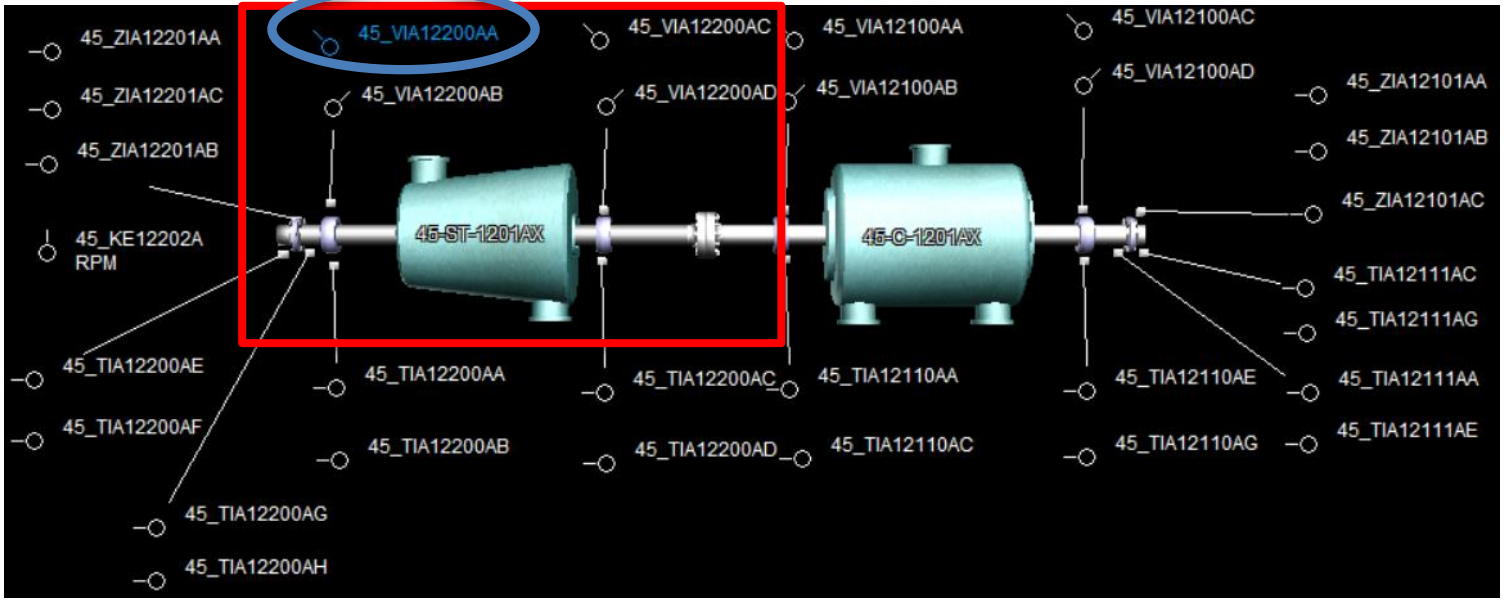


2. Problem Statement

After the machine had not run for a week without any work performed, vibration level on steam turbine bearings increased up to 5 times during its re-startup.

NDE Y-probe, 45° Left

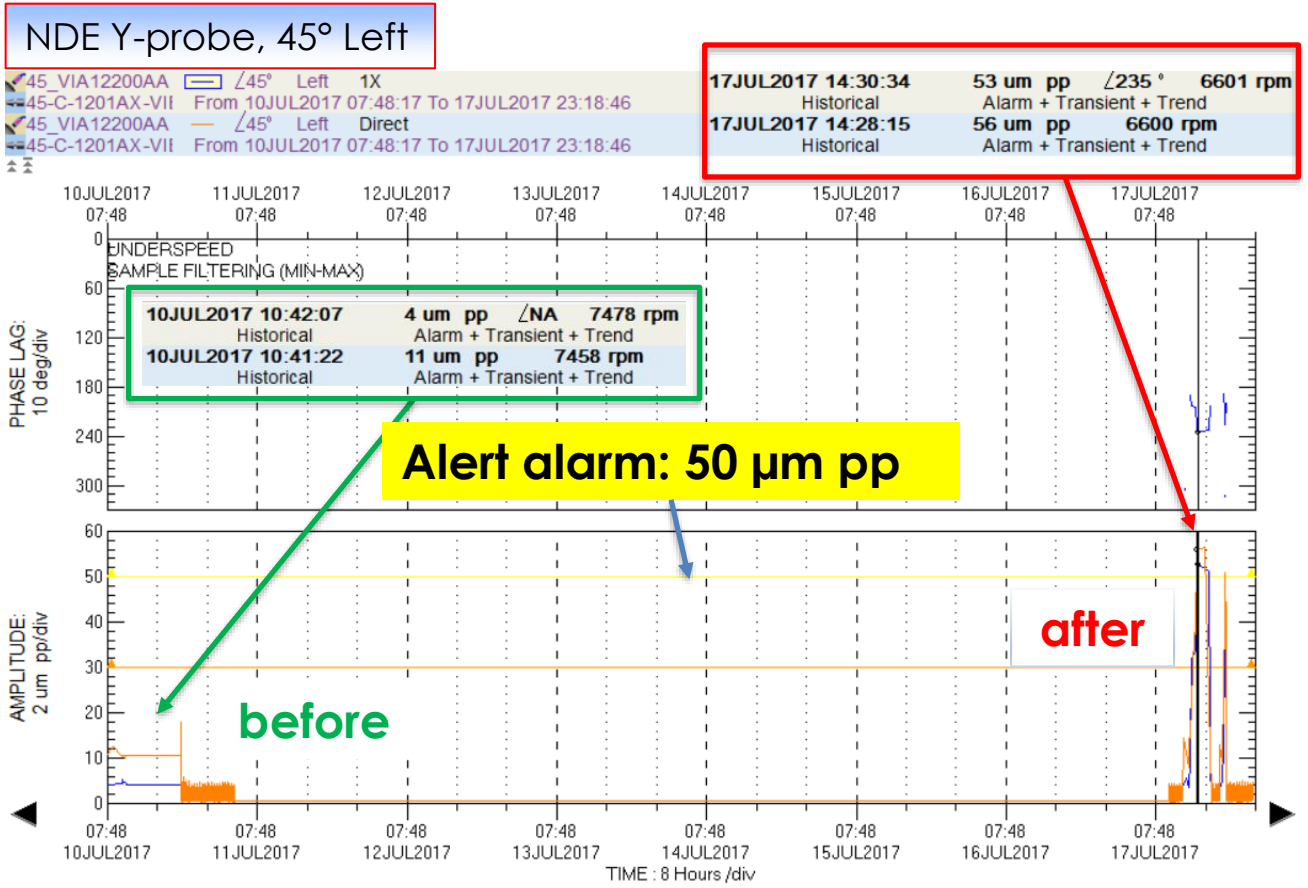
Before: 10 µm pp → After: 50 µm pp



3.1 Data Review –before & after

- **Before (July 10):**
  - ~10 *μ*m pp
- **After (July 17):**
  - 50+ *μ*m pp
  - 1X dominant

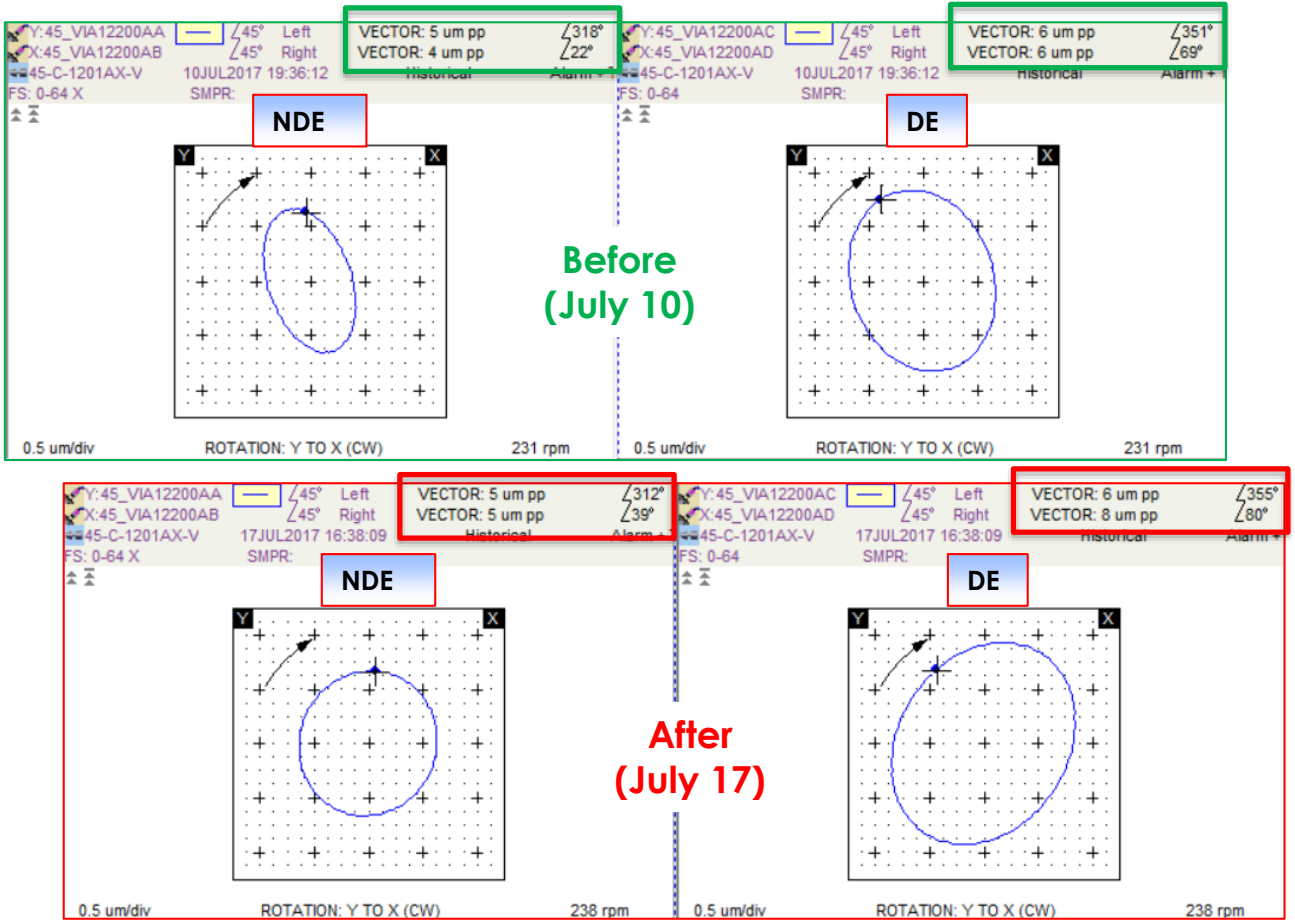
High Vibration due to 1X



3.2 Data Review – 1X slow roll before & after

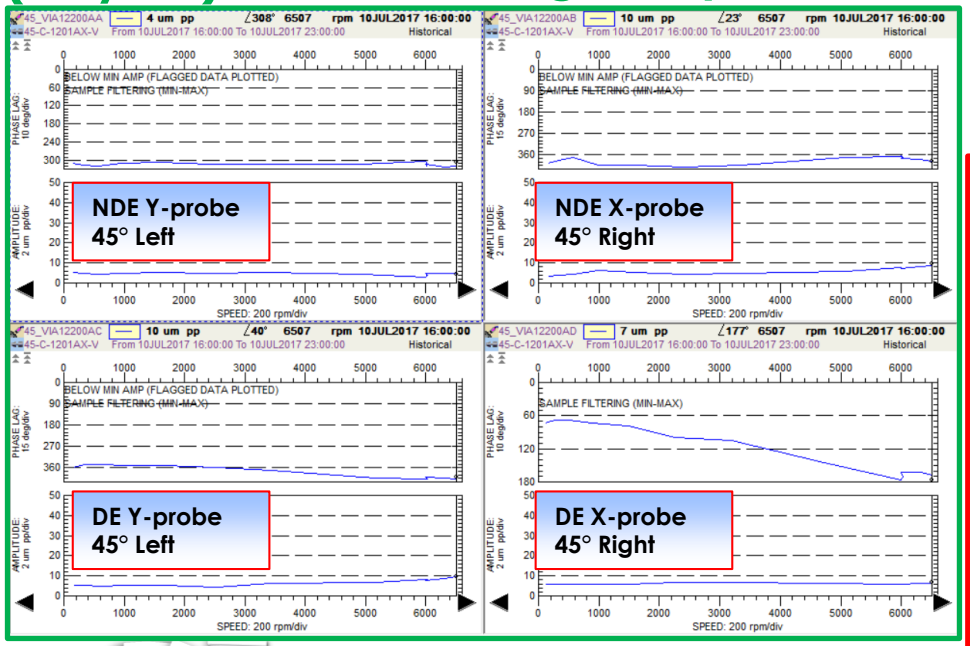
Same level of amplitudes with close phase angles

Not due to shaft bow



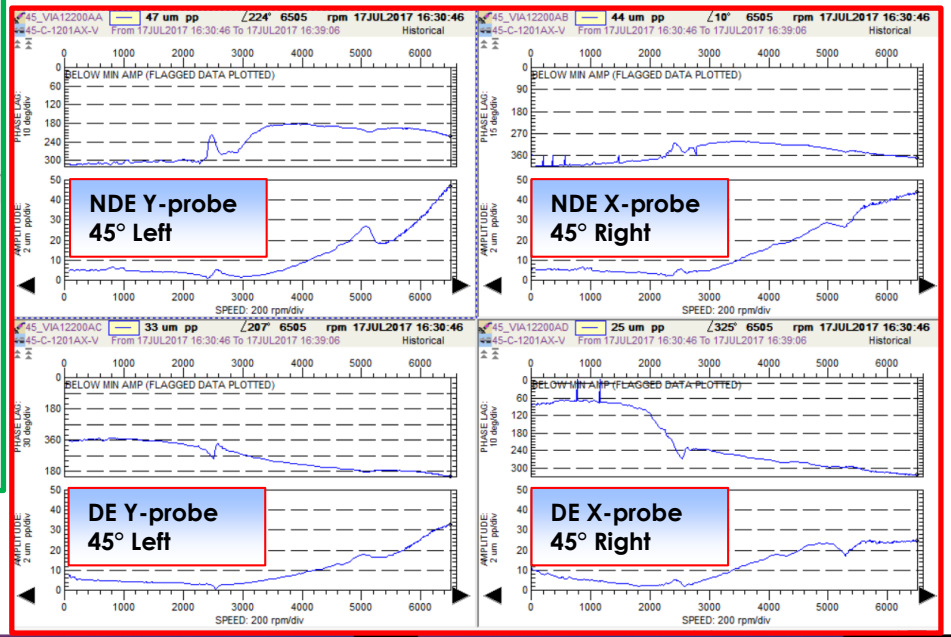
3.3 Data Review – 1X Bode plots before & after

Before : similar level as slow roll
(July 10) even at higher speed



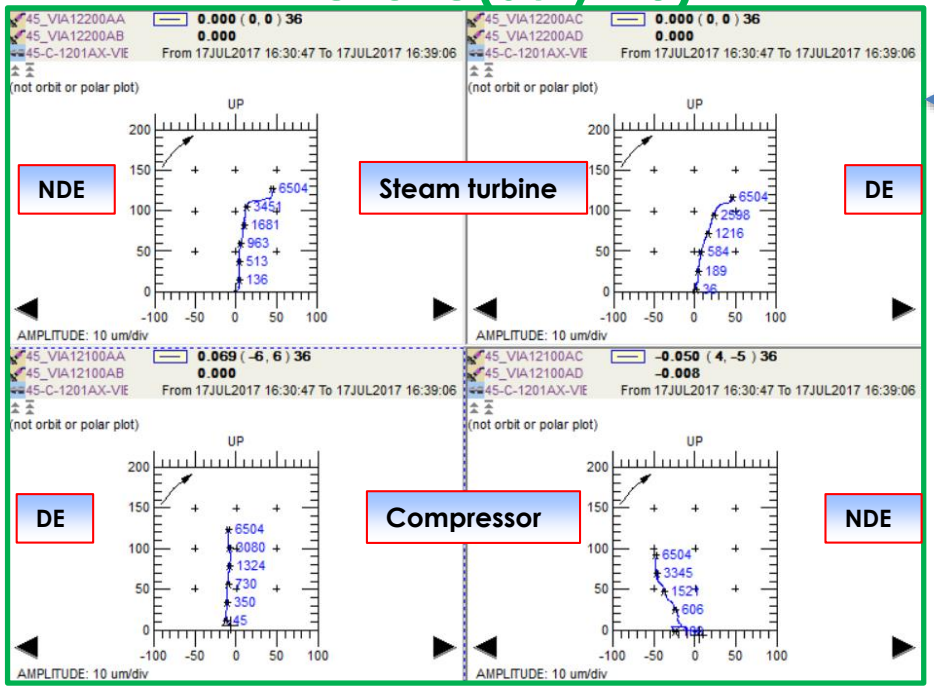
1X increasing with speed

After : Much higher than slow roll
(July 17) at higher speed



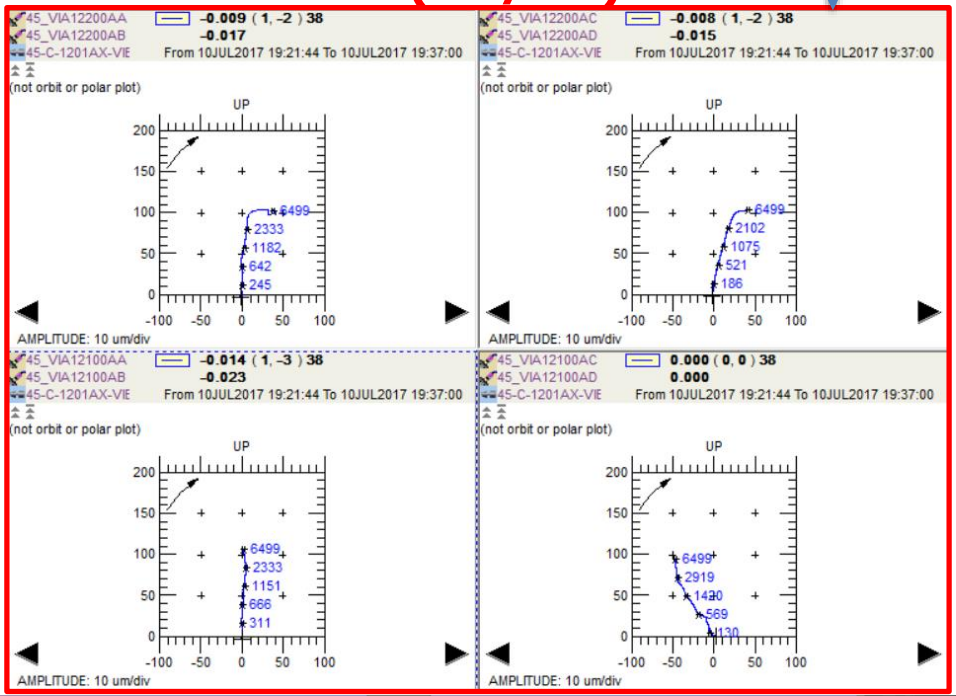
3.4 Data Review –Shaft centerline plots before & after

Before(July 10)



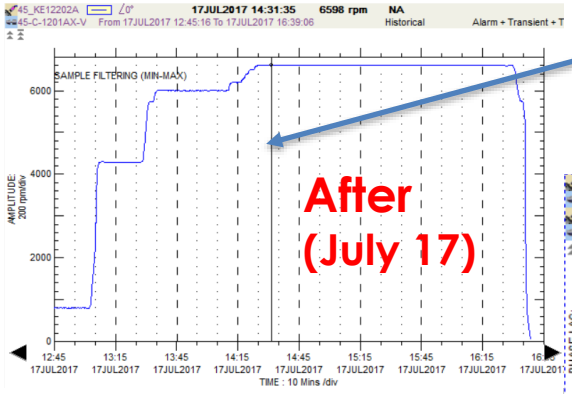
Almost identical

After (July 17)



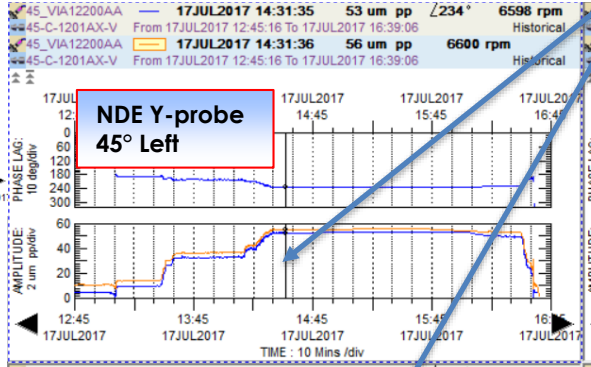
Not due to change in alignment

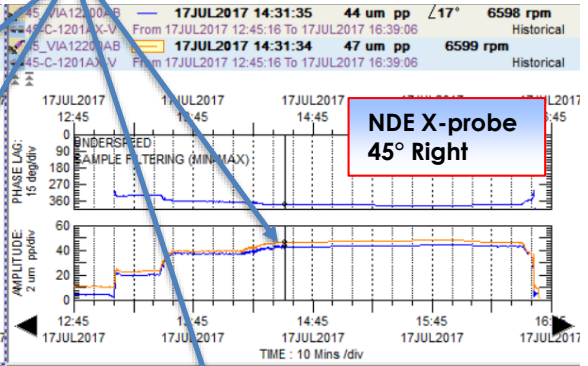
3.5 Data Review – Trend plots after re-startup

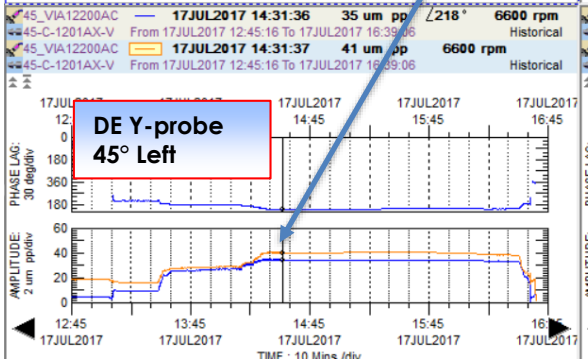


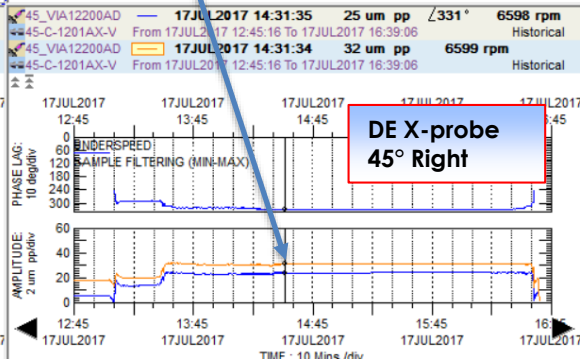
Speed trend

Direct and 1X vibration trend









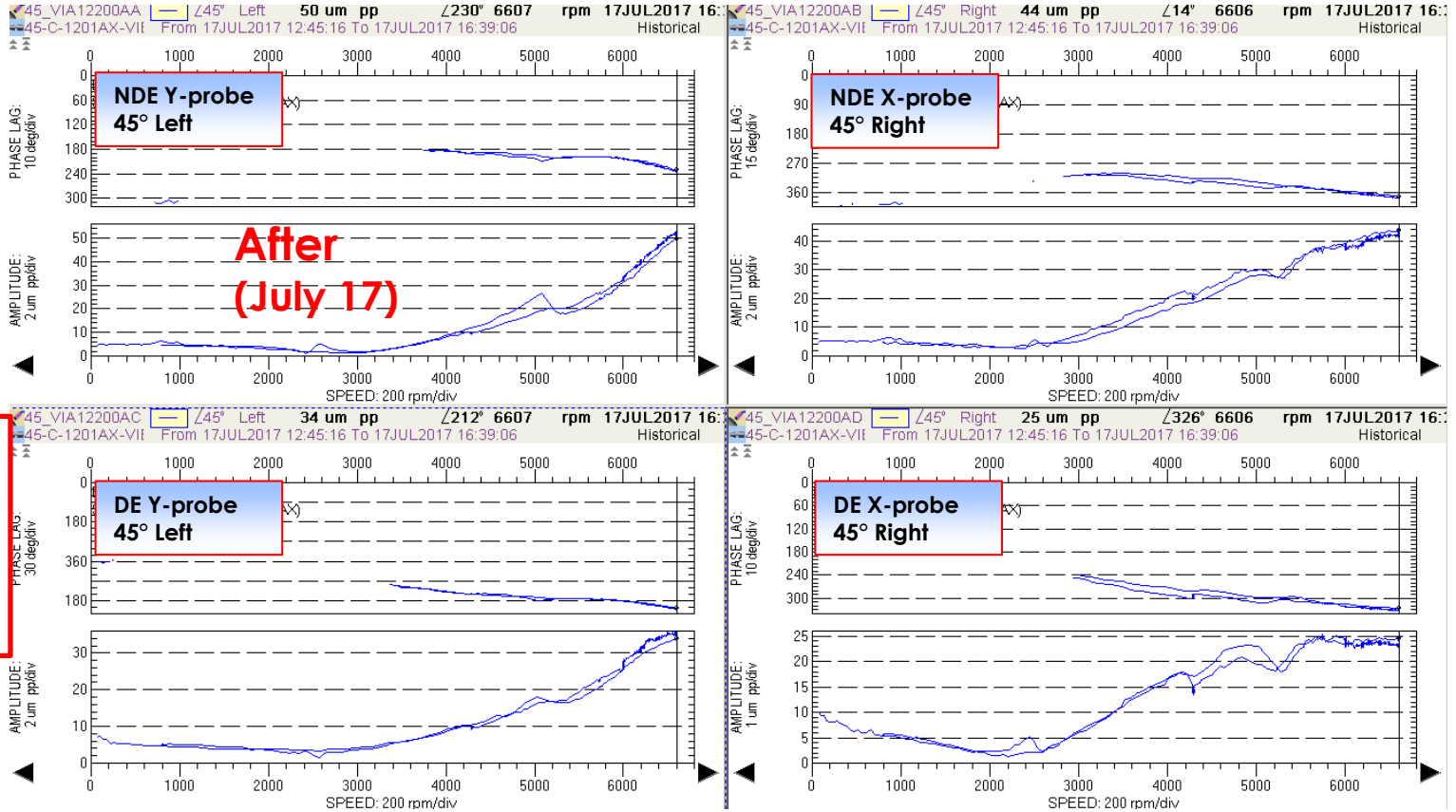
- Almost 1X
- Stable at constant speed

Not due to a rub

3.6 Data Review – Startup/shutdown Bode plots

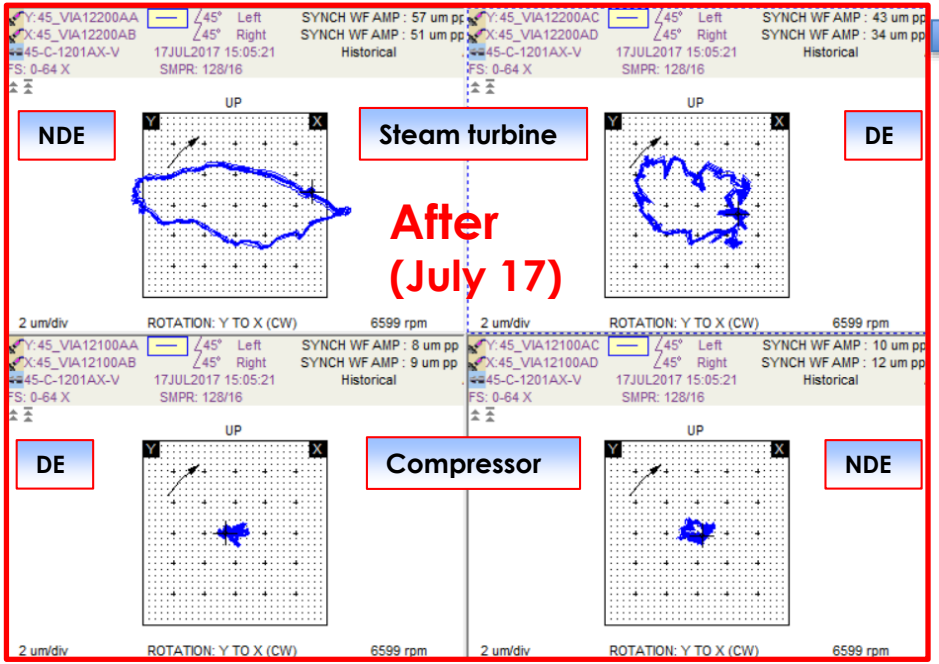
Almost identical between startup & shutdown

Not due to a rub or shaft bow

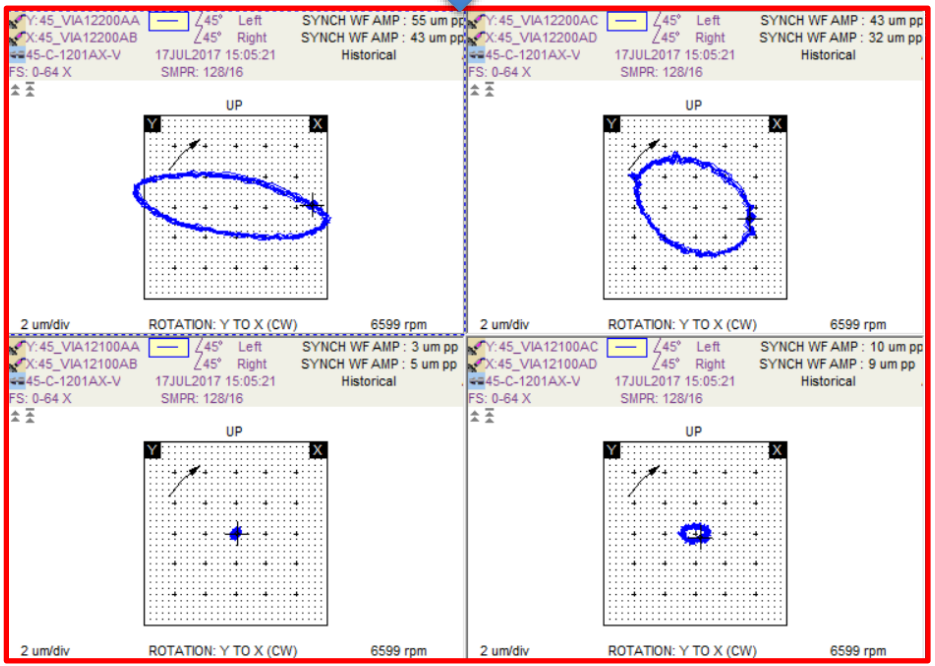


3.7 Data Review – Orbit plots at running speed

Orbit plots at all bearings



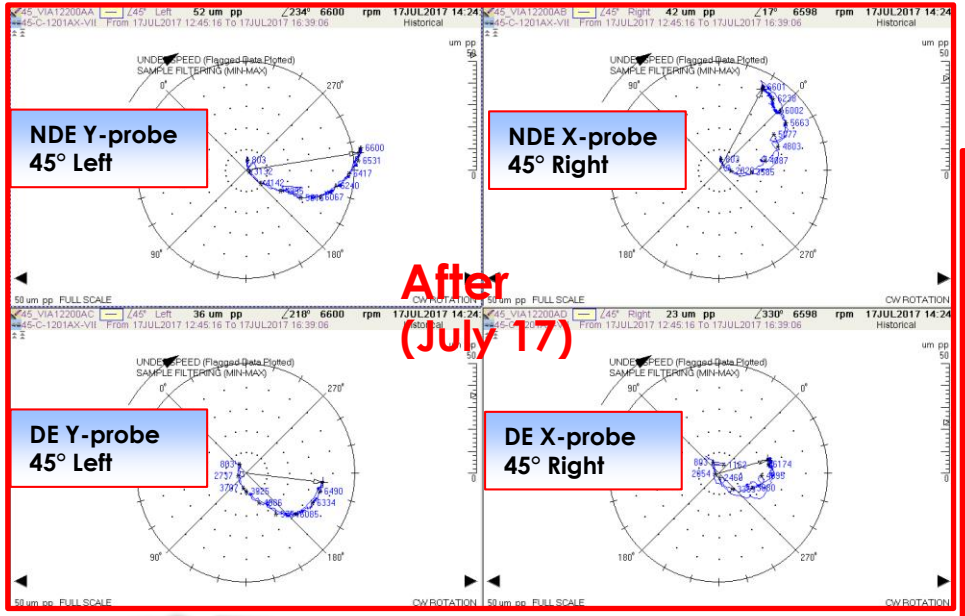
Smooth with waveform compensation



Normal orbits

3.8 Data Review – Polar plots

1st run (startup, steady-state, and shutdown)

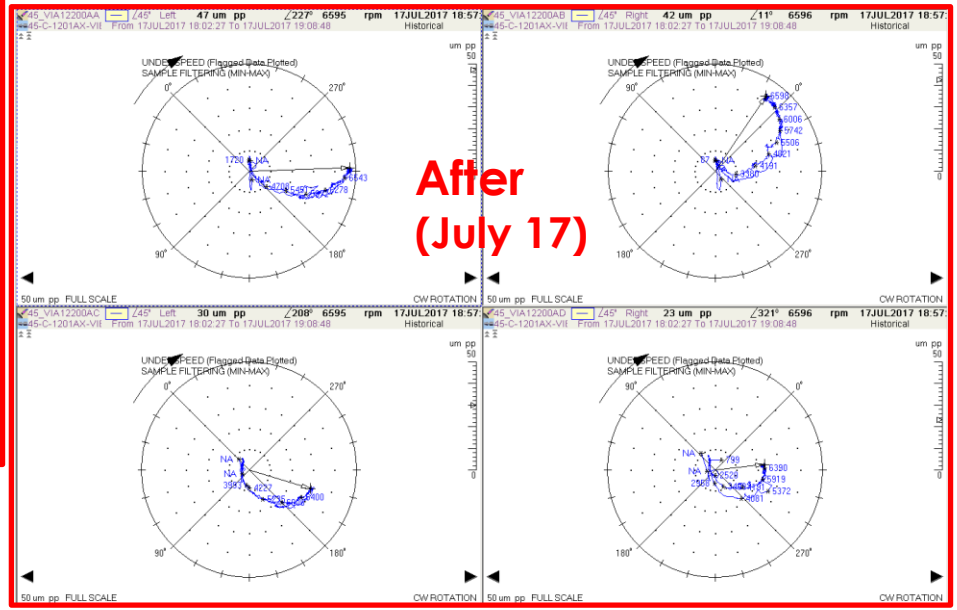


After (July 17)

Normal polar plots

Almost identical between the two runs

2nd run (startup, steady-state, and shutdown)



After (July 17)

4.1 Conclusions and Recommendations

Root-cause of much higher vibration:

- **1X component ? – Yes**
  - 1X amplitude equal to ~95% of direct amplitude
- **Shaft bow ? – No**
  - Small slow roll or runout
  - Almost identical 1X slow roll vectors before and after
- **Change in alignment condition ? – No**
  - Almost identical shaft centerline plots before and after (also ruling out piping issues)
  - Normal orbit plots

4.2 Conclusion and Recommendation

Root-cause of much higher vibration (cont.):

- **Rub? – No**
  - 1X vibration vectors unchanged at constant speed
  - Startup and shutdown bode plots almost identical
  - Normal orbits
- **Change in unbalance condition? – Most likely**
  - Typical unbalance polar plots
  - Repeatable polar plots for the two runs on July 17

4.3 Conclusions and Recommendations

Conclusions:

- A change in unbalance caused high vibration.
- The reason of the change cannot be determined.

4.4 Conclusions and Recommendations

Recommendations

- **Balancing without inspection?** X

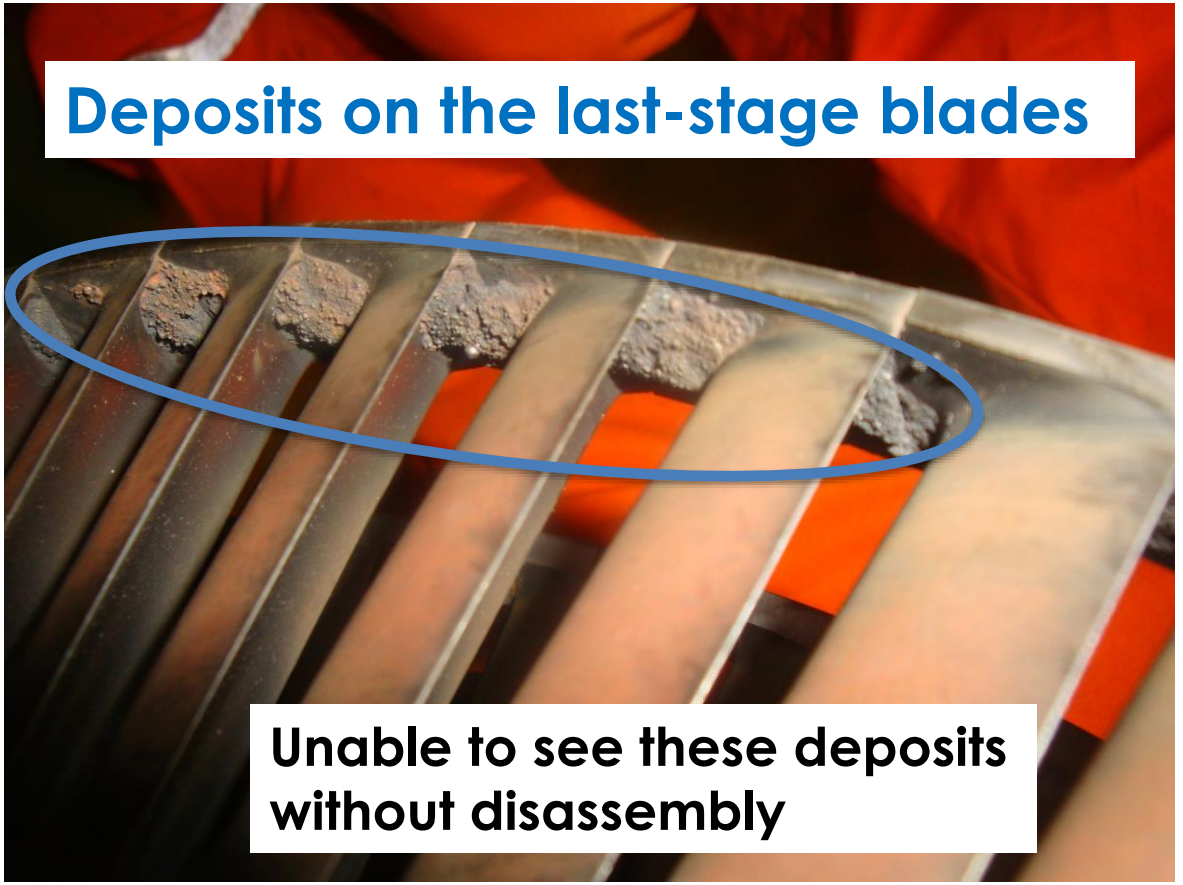
A quick solution to let turbine back in operation without knowing the root-cause of the unbalance change. Could be a risk in the future.

- **Opening the case for inspection ?** √

Can examine the root-cause of unbalance change and lead to a correct action, though time-consuming.

5.1 Inspection and Findings

- Large amounts of deposit at each stage found, from less to more in order from inlet to outlet.
- The coupling and shaft runout in good condition



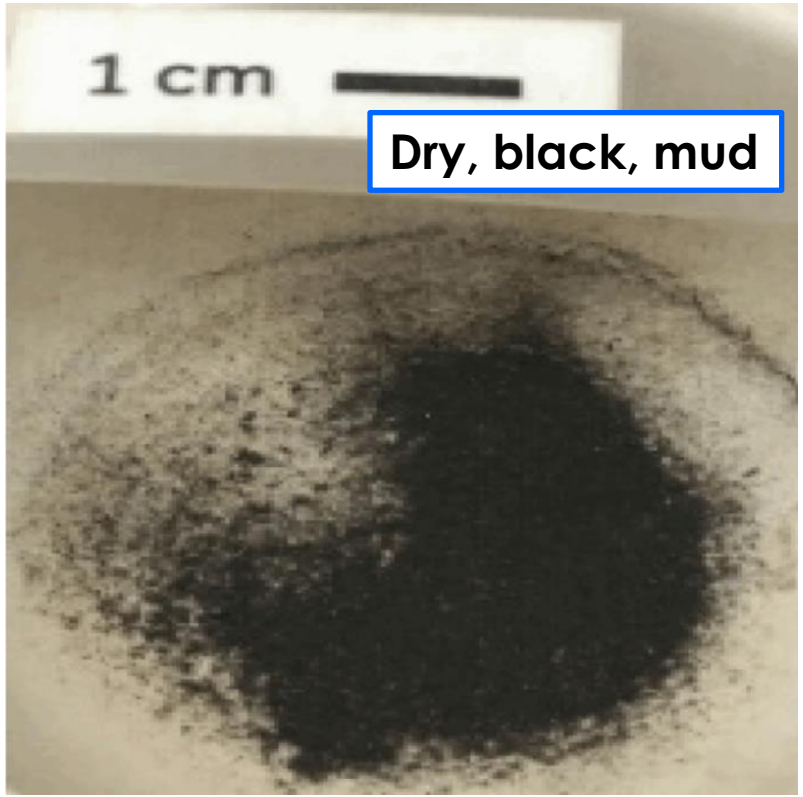
5.2 Inspection and Findings

- Some deposits dripped when the rotor was lifted during disassembly.
- The deposits were later all removed from the turbine blades.
- A shop-balance check concluded that the turbine rotor without these deposits was within the balance tolerance.
- This demonstrates that the source of new unbalance came from the deposits on turbine blades.

5.3 Inspection and Findings

- A sample of deposits analyzed, and its elements (checked from Sodium to Uranium) found to be mainly magnetite, or iron, Fe_3O_4 (90%).
- The deposits likely came from the boiler or some paths between the boiler and the turbine.

Photograph of the sample

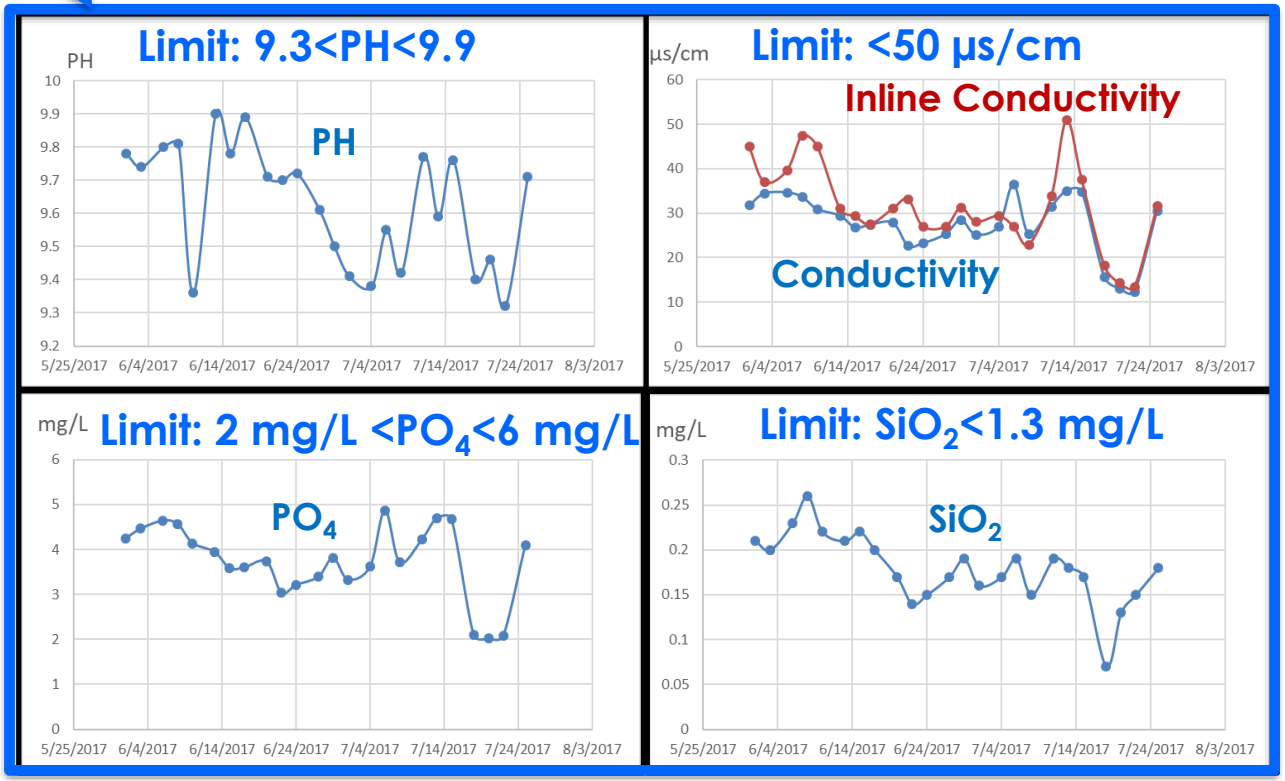


5.4 Inspection and Findings

- Such large amounts of deposit accumulated on turbine blades seems to be unusual.
- The 7-day non-running period could have created these deposits somewhere before entering to the turbine, unevenly accumulated on turbine blades.
- It was also possible that these deposits had been accumulated gradually and evenly for a long time. When the turbine was not running and became cold, some of deposits might have dropped during the initial turning, causing uneven distribution of deposits on turbine blades.

5.5 Inspection and Findings

- Boiler water quality seemed normal around that period.
- Deaerator will be checked during next outage to examine any corrosion.
- The other sister unit will be inspected during shutdown as well.



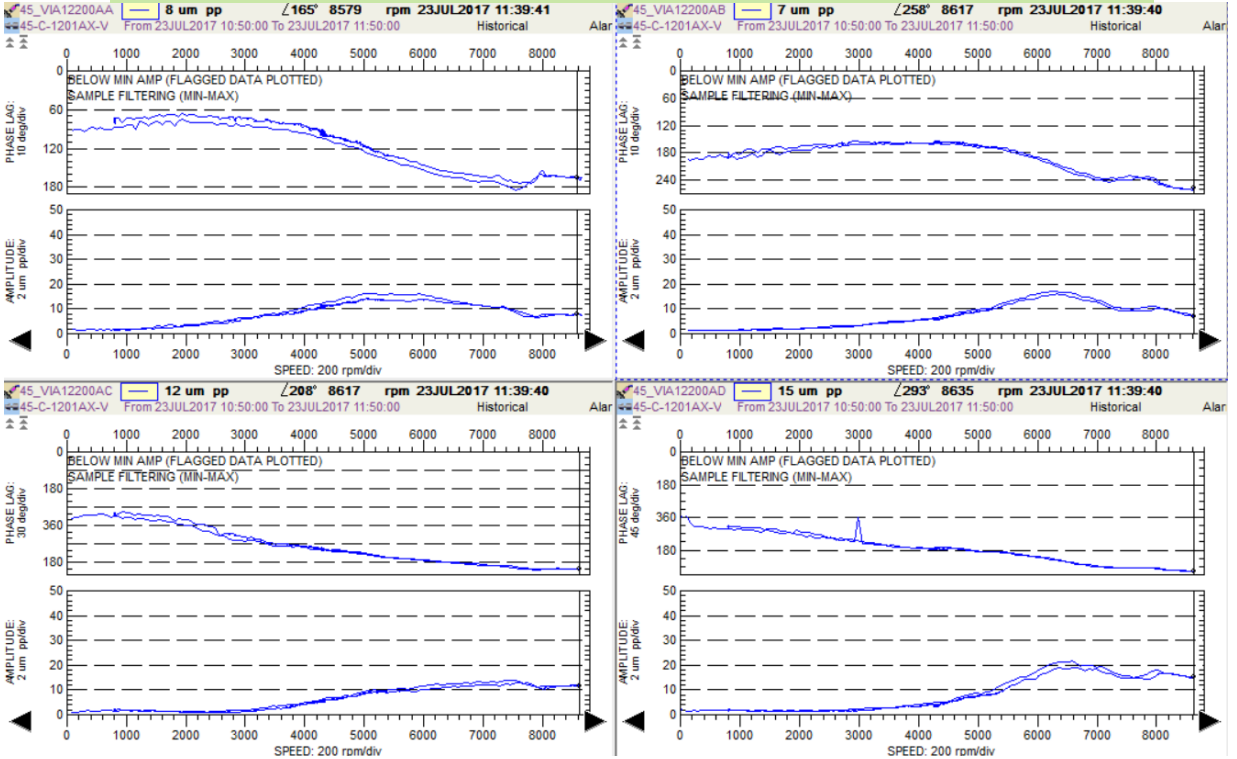
6.1 Resolution and Final Vibration Results

- To ensure safe and quick return of normal operation, the old rotor was replaced with a new one immediately after disassembly.
- To ensure no other issues besides the deposits, the old rotor was send to workshop for balance check and inspection as indicated before.

6.2 Resolution and Final Vibration Results

1X vibration on the new steam turbine rotor from 0 to 8600 rpm

1X vibration on the new steam turbine rotor below 20 µm pp at all speeds up to 8600 rpm,



7. Lessons Learned

- In this case, if onsite balancing had been performed to have a quick fix, the root-cause of elevated vibration would not have been identified and future high vibration would occur suddenly with possible damage to the turbine. This would then lead to unscheduled equipment downtime, and unanticipated maintenance cost.
- This case also shows that steam turbine deposits, though uncommon, could occur. Understanding the source and cause of deposits is crucial to prevent them from occurring again in the future.